DOCUMENT RESUME

ED 187 706 SP 016 173

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TITLE Strength Training. A Key to Athletic Training.
PUB DATE 80
NOTE 22p.

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Exercise Physiology; *Muscular Strength; *Physical Development; *Program Administration; *Program Development; *Training Methods; *Weightlifting

ABSTRACT

Characteristics of an effective strength training program are analyzed and descriptions are offered of different kinds of weight training activities. Comparisons are made between concentric, isometric, eccentric, and isokinetic training methods. The fundamentals and techniques of an exemplary training program are outlined and the organization and administration of such a program are discussed. (JD)

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STRENGTH TRAINING

A KEY TO ATHLETIC TRAINING

U.S. DEPARTMENT OF HEALTH,
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TABLE OF CONTENTS

PAGE

Introduction. 1

Picking a Program- Concentric, Isometric, Eccentric or Isokinetic 2

Concentric Training 3

Isometric Training. 4

Eccentric Training. 4

Isokinetic Training 5

Comparisons of Strength Training Programs 5

Fundamentals and Techniques 6

A. Warm Up. 6
B. Muscle Size and Strength-Physiological Implications 7
C. Muscle Soreness. 8
D. Proper Training Techniques 8
E. Breathing. 8
F. Exercise Antagonists 8
G. Exercise Through a Full Range of Motion. 9
H. Positive and Negative Work 9
I. Intensity. 9
J. Recording of the Workout 10

Organizing a Weight Training Program. 10

Principles of Strength Training 12

Administration of the Strength Training Program 14

Summary 16

Footnotes

Bibliography

Introduction

For centuries mankind has been concerned with physical strength. Prehistoric man was very dependent upon his physical prowess for survival. The non-technical nature of warfare in early civilzations put a premium on the individual strength of the soldier because of the predominance of hand-to-hand combat. The Greek Spartans held physical strength and development in such high esteem that harsh disciplinary measures were taken against those who did not strictly adhere to the training regimene. The Greeks also had an aesthetic appreciation of a well developed body. During the long rule of Rome, emphasis was placed on strength and physical development. This was an outgrowth not only of military training but of the acclaim and fame won by the gladiators. The success of knights of medieval times in contest and battle depended a great deal upon development of physical power. Strength is a factor commonly attributed to the stereotype of the tough, man-of-action, pioneer type. Technological progress of modern civilizations and accompanying sedentary occupations have decreased the need and importance of strength development for many individuals. Strength, however, is still a basic requisite for skilled participation in most sports. In general, championship performance in a sport is indicative of a greater than average amount of strength development in the participant.

Authorities differ on what factors constitute a good weight training program. Some believe that the amount of resistance or weight used, the number of muscle constractions against the resistance, and the speed with which the repetitions are performed are all determining factors in achieving maximum efficiency in strength development.

There has been a great deal of controversy as to which strength training program is the most effective and efficient in overloading the muscle fibers

and subsequently producing the greatest development of muscular strength. All strength training methods overload the muscle fibers by creating tension in them. The difference in the various methods appear in the movements of the muscle fibers when they create this tension. The concentric method produces the tension by a shortening of the muscle fibers against a resistance during the contraction phase. Isometric training creates the necessary tension by contracting the muscle fibers against an immovable resistance and therefore there is no observable movement of the fibers. Eccentric training overloads the muscle by causing a lengthening of the fibers during the contraction phase. This lengthening contraction is due to the greater magnitude of the resistance as compared to the force exerted by the muscle. Isokinetic training provides the necessary tension by holding the speed of the body movement constant, therefore a maximal exertion of muscular force is produced at all angles of the movement. Lastly, the joining of these various techniques into combined training programs has also been used to develop muscular strength.

The utilization of the physiological principles of muscular contraction have aided in the development of all strength training techniques. Coaches, trainers and athletes are increasingly beginning to accept the value of strength training as a supplement to improve athletic performance. Research and experimentation has provided the most efficient means of determining which methods elicit the most effective strength gains. The following section will deal with the difference methods of training.

Picking a Program - Concentric, Isometric, Eccentric or Isokinetic

Studies in the physiology of muscular work demonstrate that the efficiency of muscular contraction depends upon there being an optimum load on the muscle. Consequently, a muscle that is overloaded has a smaller work efficiency than one which is not loaded too heavily. The person of less than normal strength,

in addition to his constance fatigue, is always working at a relatively lower level of efficiency than would have been the case had his strength been up to normal for his weight.[1]

A study by Steinhaus indicated that muscles increase in size and strength when exercising with gradually increasing loads up to a point where maximal pulling power is involved. Humans reach peaks of strength between the ages of twenty-six and thirty with a gradual decline in strength thereafter. Hereditary factors such as size and structure limit the individual's capacity to benefit from exercise.[2]

Concentric Training

DeLorme proposed the use of heavy resistance exercises to overload the muscle. He believed that heavy resistance and low repetition exercises were necessary to build strength and that low resistance, high repetition exercises produced endurance. He experimented with his program of heavy resistance exercises in an effort to find the best method for building strength in people with orthopedic and muscular disabilities. The patients exerted maximum power once a week. During the rest of the training periods the exercises were done with resistances with which ten repetitions could be performed. DeLorme later felt that "heavy resistance exercises" gave the wrong connotation to his training program, so he changed the term to "progressive resistance exercises."[3] He established that the resistance should be regulated to the strength of the muscle but should tax the muscle to its limits. He also cut down on the number of sets of repetitions per training period, because he felt the same degree of improvement could be obtained with fewer repetitions.

DeLorme's training method was as follows: Monday through Thursday ten sets of seven-ten repetitions per set (70-100 contractions) were performed. Friday was the limit day and a new weight level was determined. The rest

over Saturday and Sunday was to allow for the adaptation of the muscle for future workloads.

The three main factors in strength training programs are the force of the contractions, the length of time of the contractions, and the number of repetitions. The development of progressive resistance continued as Berger varied the number of sets, repetitions per set, and exertion per set.[4] The training sessions were held three times per week for twelve weeks. As strength increased, adjustments were made by adding weight so that the prescribed number of repetitions were performed. The optimum number of sets and repetitions maximum were three and six, respectively.

Isometric Training

Static or isometric contractions were developed as a means of stressing the muscles and therefore causing increases in strength. Such contractions control the distance moved during a muscular contraction. There is no observable movement of the limb however, the muscle is being stressed and therefore some overloading effect is taking place.

Isometric training became very popular in the 1950's. This was partly due to a report from Germany which stated that when subjects were trained with two-thirds maximum contraction and held this contraction for a period of six seconds, a significant increase in maximal isometric strength was elicited. The training sessions were held once a day and the training stimuli was adjusted as the maximal strengths increased. It was also noted that performance of these contractions at maximal limits would produce no greater strength increases than the two-thirds maximum, six second daily contraction.[5]

Eccentric Training

The experimentation with eccentric contractions and strength development maintains that muscle tension is of major importance in the development of

muscular strength. Studies which have compared positive (concentric) and negative (eccentric) work have utilized the use of two subjects working against each other. The tension levels of the eccentric subjects were considerably higher than those of the subjects working concentrically. The use of fewer muscle fibers and therefore more tension per muscle fiber was also noted as occurring during an eccentric workout.

Isokinetic Training

The concept of isokinetic exercise was presented by Hislop and Perrine in 1967 as a new technique for strength development. The concept of isokinetic exercise is to control the speed of muscular performance. This is achieved by, "holding the speed of the body movement at constant rates irrespective of the magnitude of forces generated by the participating muscles."[6] Consequently, the muscle is exerting its maximal force at all angles of the movement. Isokinetic exercise is also referred to as accommodating resistance exercise.

Comparisons of Strength Training Programs

Comparisons between concentric, eccentric, isometric, isokinetic, and combined training programs have revealed contradictory results with regard to the superiority of any one method in eliciting strength gains. The controversy that exists between these investigators may lie in the differences in experimental techniques used in comparing the different training programs. Any investigation that compares different training methods must keep the workouts equal with regard to stress of training, rate and number of contractions, and utilization of testing procedures directly related to the training movements. The elimination of bias in favor of one program over the others, by equalizing as many variables as possible, is of major importance in any comparative training research. To date, the studies reviewed were all contradictory, and therefore no major assumptions or conclusions can be made.

Fundamentals and Techniques

In order to have an effective strength training program basic skills and guidelines must be established. The fundamentals and techniques discussed in this section strive to train in the safest manner possible, while maximizing gains in muscular development. This section will deal with ten different areas which are relative to establishing an effective strength training program.

A. Warm Up

The term "warm up" in this context refers to the use of preliminary exercise procedures. The principle of warm up is still the subject of considerable debate among researchers in the physiology of exercise. Studies by most investigators have indicated that there are beneficial effects on performance as the result of warm up. Others seem to doubt the effectiveness of this procedure.

One of the real values of the warm up is in its use as a preventative measure. It has been shown that adequate warm up prevents strains, muscle tears, and muscle soreness that would probably occur if the athlete went into full performance without such a preliminary.[7] The main purposes of warm up are to raise both the general body and the deep muscle temperatures and to stretch the ligaments and other collagenous tissues in order to permit greater flexibility. This reduces the possibility of muscle tears and ligamentous strains and helps to prevent muscle soreness. As cellular temperatures incerase, it is accompanied by a corresponding increase in the speed of the metabolic processes within the cells. At higher temperatures, a faster and more complete dissociation of oxygen occurs from the hemoglobin, which improves the oxygen supply during work.[8] A speed up in the transmission of nerve impulses also occurs, with a resultant increase in the athlete's

physical working capacity. The length of the warm up varies with individuals. Usually five to ten minutes of activity is sufficient to raise the core temperature of the body. Suggested warm up activities would include stretching, large motor movements, running in place, and lifting very light weights through the ranges of motion specific to the exercise in the weight training program.

B. Muscle Size and Strength-Physiological Implications

Strength is defined as the capacity to exert force or as the ability to do work against resistance. The most noticeable change that takes place is the increase in girth. Size alone is not an index of the strength of a muscle. Muscles of the same size is an individual may very considerably in strength because of the difference in the amounts of adipose tissue each contains. Fat possesses an inhibiting quality with respect to muscle efficiency, it lacks contractile power and limits the speed and amount of contraction.

Muscular strength can show an increase of three times or more without a propostional increase in muscle bulk. However, to increase strength exercise must be performed against near maximal and gradually increasing resistance utilizing the overload principle. Several factors are important to remember while developing a strength program. The speed, the duration, the number of repetitions, and the force with which exercises are performed will determine the outcome of the program.

General concensus favors the hypertrophy theory which states the following: The increase in muscle cross section is caused by a development of the existing constituent fibers when strength exercises are employed and by an increase in the total number of capillaries called into play when exercises of endurance are employed.[9] A gain in strength is accompanied by a significant increase in both the size of fibers and the number of capillaries in the muscle and by

a resultant gain power, speed, and endurance.

C. Muscle Soreness

Muscle soreness usually occurs in the initial stages of a properly conducted weight training program. An unaccustomed amount of physical work or tension on the muscles causes a build up of waste products, lactic acid and carbon dioxide, which accumulate faster than the body can use or remove them. The best way to relieve muscle soreness is by gradual stretching of the agonists and antagonists involved. It is also suggested that three to four sessions of normal workout intensity will alleviate some of the soreness.

D. Proper Training Techniques

Each weight training program must follow the specific methods and techniques that are recommended in order to obtain the highest degree of success. The athlete who is lifting weights for the first time should devote the first few workouts practicing the basic movements involved in each exercise with relatively light resistance in order to gain familiarity with the equipment.

E. Breathing

An individual should synchronize their breathing in weight training with the exercise. Physiologically there is a need for breathing during every repetition of all exercises. The most consistent and efficient method that can be utilized is to inhale whenever the resistance is being lowered or pulled toward the body and exhale when the resistance moves away from the body.[10]

F. Exercise Antagonists

It is necessary to achieve a balance of strength in opposing muscle groups. Pairs of muscle groups which oppose each other are called antagonists. These muscles must be kept in equilibrium or balance in order to have the most efficient strength training program. If one muscle becomes

stronger than its antagonist, the flexibility of the joint controlled by the affected musculature is decreased. As a result, both the joint and the involved muscles are more susceptible to injury.

G. Exercise Through a Full Range of Motion

Most experts in sportsmedicine consider flexibility, or the capacity of the joint to move through a full range of movement, one of the most important objectives of any weight training program. The primary factor affecting that capacity is the musculature surrounding the joint. When the joint is periodically required to go through a full range of motion, the involved muscles retain their natural elasticity. If this does not occur, the athlete usually has a decrease in their ability to perform and the possibility of injury increases. Properly performed weight training exercises actually increase flexibility, if done through a full range of motion.[11] Adherence to correct lifting techniques will enable the athlete to develop strength throughout the entire range of movement for the body's musculature.

H. Positive and Negative Work

Weight training deals with two distinctive moves: the raising of the weight is considered positive work and the lowering of the weight is negative work. The positive phase involves shortening or contracting the muscle. During the lowering phase the muscle is lengthened. The muscles used to raise the weight are the same muscles used to lower the weight, the muscle is shortened on the lift and lengthened when lowered. Both phases are extremely important in order to have the most efficient strength training program.

I. Intensity

The higher the level of intensity in a weight training program the greater the increase in muscle development. The level of intensity is determined by three factors: (1) the effort extended by the individual,

(2) the use of proper training methods and techniques, and (3) the equipment used in the conditioning program.[12]

The effort that is extended is the most important of the three factors, which attributes to the intensity of the work out. The effort is maximum when the lifter reaches a point of momentary muscle failure. The use of a training partner is the most effective way of insuring that the athlete pushes himself to his upper physical limit. Regardless of the equipment being used, a maximum effort must be extended and all the proper training techniques must be observed to achieve high level intensity and maximum gains in muscular development.

J. Recording of the Workout

The amount of resistance lifted and the number of repetitions performed should be recorded for each exercise. Recording will help eliminate duplication of previous workouts, while providing incentive and motivation for improvement. The athlete should strive for a certain degree of continual progress in muscular development.

Organizing a Strength Training Program

In order to organize an effective muscular development program, the athlete must be familiar with specific muscles and muscle groups of the body, the action of each muscle during physical exertion, and the exercises necessary to develop each muscle or group. A program is functional if it is specific in developing the muscular development required to meet the objectives of the athlete's conditioning program.

Objectives must be established when organizing a program for muscular development. Basically, four areas can be identified: bodybuilding, rehabilitation, competitive lifting, and weight training. The goal of bodybuilding is to improve the appearance of the body. Rehabilitative weight lifting is

done to return the athlete to pre-injury levels of fitness and to minimize the possibility of reinjury. Competitive lifting is usually done between individuals or teams to see who can lift the most weight. In weight training the primary objective is to improve the athlete's level of muscular development so that athletic performance is improved.

A sound strength training program must be based on valid and reliable scientific principles and research. The task of the athlete, coach or trainer is to separate fact from fiction when developing a program. There are seven basic variables that should be examined when developing a program: repetition, set, frequency of workout, exercises to be performed, order of exercise, workload, and time interval between exercises.

A repetition (rep.), the number of times a lift is performed, must be done between 8 and 12 times in order for maximum muscle recruitment and development. For maximum efficiency the athlete must strive for momentary muscle failure.

A set consists of the total number of repetitions executed each time an exercise is performed.[13] The point to be remembered is that maximal effort should be exerted in order to increase muscular efficiency. Therefore it is not necessary to do numerous sets, if a maximal effort is exerted for one properly completed set.

The frequency of a workout refers to the number of training sessions in one week. Most experts recommend that lifting should occur on alternate days, and done three times per week. It has been proven that the muscle will start to atrophy or shrink after 48-72 hours. It should be stressed that hard work in moderation is the key to any exercise program if the muscles are given time to rest and adapt to the stresses of the previous workout.

The exercises that the athlete performs will be dependent upon their program objectives and the muscles or muscle groups that need to be strengthened.

Most often the coach or trainer will decide which exercises are most necessary according to a mechanical analysis of the sport. Once the prime movers have been identified then a specific program can be developed to encorporate exercises for strengthening

The order of exercise is dependent upon the strength of the individual segments of the body. It is recommended that the largest and strongest muscle groups be exercised first, followed by the smaller and weaker groups. Consequently, the proper order of exercise would be: hip-back-legs, torso, arms, abdominals and neck.

The amount of weight to be used when performing an exercise is termed the workload. Momentary muscle failure must be reached in order to obtain maximal gains in strength. It is vital to remember that the exercise must be performed properly to be most beneficial. One set of proper techniques is far more advantageous than four sets done improperly. The athlete should never sacrifice form or technique to increase the amount of weight to be lifted.

There is controversy in the literature as to the most effective time interval between exercises. Riley suggests that in a strength training program, as much time as is needed to adequately recover from one exercise before going onto the next exercise should be allowed.[14] An adequate recovery would be exhibited by the athlete's ability to perform another maximum effort of any given exercise.

Principles of Strength Training

Weight training should be considered as a means of increasing athletic performance by increasing strength, and also as a means of prevention of injury. Muscular imbalance, poor neuro-motor co-ordination, a lack of ligamentous or muscular strength, lack of flexibility, and inadequate muscle bulk are among the causes related to injury. There are six basic principles that

should be followed in order to have the most effective and efficient program. They are as follows:

(1) Strength training must be progressive. Increasing the strenuousness of exercise is an application of the overload principle. This principle states that an activity must always be upgraded to a consistently higher level through maximal or near maximal stimulation. In this way the metabolic level and organic responses can be increased.[15] An exercise is complete only when the athlete is unable to do any additional movement. Best results are usually obtained when a set involves at least eight repetitions and not more than twelve.[16]

(2) Strength is directly related to the intensity of the exercise. Intensity of contraction occurs when a muscle is producing as much pulling force as it is momentarily capable of doing. Only the number of fibers that are actually required to move a particular amount of resistance are involved in any movement. This concept is known as the "all or none theory", where as many as possible of the available fibers have been used, and where at least some of the fibers have been worked to a point of total failure. A set that is terminated prior to the point of failure will not involve the maximum available muscle fibers. A reduction in the intensity of effort will cause a decrease in results.[17]

(3) Every repetition should be performed at a slow speed of movement, a full range of movement, and a pre-stretching of the involved muscles.[18] It is necessary to perform a repetition in a slow, smooth manner so that a steady force is applied through a full range of motion. Attention should be paid to the eccentric contraction phase, or the lowering phase of each exercise. More benefit is derived from the lowering of the weight, as opposed to the lifting of it. Consequently, the experts recommend a two second period of time to lift the weight, and a four second period of time

to lower the weight.

(4) Major muscle groups should be exercised to their maximum through a full range of movement. Certain pieces of equipment are more efficient when dealing with this principle. For example the Universal Gym or barbells do not give maximum resistance through a full range of motion, however Nautilus Equipment is very effective concerning this principle. Exercises that are of most value are those which involve the greatest possible mass of the muscle.

(5) Experts agree that the largest muscle masses should be exercised first, followed by the smaller, weaker ones. This principle is based upon the fact that smaller groups of muscles will fatigue first. If these smaller muscles are a link between the resistance and the larger muscle groups, muscular failure of these smaller groups will inhibit the athlete from maximally fatigueing the larger groups.

(6) Brief and infrequent training periods result in the most efficient increases in strength. High intensity work must be followed by an adequate rest period so that muscular growth and strength will increase. There should be at least 48 hours rest between workouts, but not more than 96 hours.[19]

Administration of the Strength Training Program

In order to administer an effective weight training program it is necessary to adhere to the techniques and principles discussed previously in this paper. It is also vital to obtain full co-operation of all involved - the coach, trainer and athlete. There are three basic administrative guidelines to follow when organizing a strength training program:

(1) The order of the exercises should be established and adhered to no matter what equipment is being used. The coach will usually decide on the type of equipment, depending on what is available. Each piece of weight training equipment should be put in the specified order according to large and small muscles for efficiency and to avoid confusion. This will allow

for a smooth and controlled movement of athletes through the exercises. By adhering to this guideline it will be possible to train the largest number of athletes most efficiently.

(2) Training partners should be assigned so that the entire workout is supervised and the maximum work output is obtained. To have the best possible program, an athlete should never train alone. Safety is mandatory, as is the proper execution of each exercise.

(3) Training times should be assigned to each pair of athletes to avoid waiting periods at any piece of equipment. The athlete should not be allowed to rest between stations. An adequate amount of time should be allotted to complete each exercise. This limiting time element will force the athlete to complete the exercises in a minimum amount of time.

Summary

The inherent values of weight training are recognized by trainers, coaches and physicians. A review of the literature reveals various methods of weight training: concentric, isometric, eccentric, isokinetic, or a combination of programs. It has taken a long time for individuals to recognize the fact that there is a distinct difference between bodybuilding, rehabilitative exercises, competitive training and weight training. Most weight training systems currently in use today are based on the DeLorme method of progressive resistance exercises (PRE), utilizing the overload principle.

A properly administered weight training program will adhere to the various fundamentals, techniques, and principles as discussed in this paper, and recommended by the experts. Maximum gains in strength will be acquired if the proper techniques are followed. These administrative principles and guidelines should be maintained in order to have the most effective and efficient program available.

FOOTNOTES

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[13] Daniel P. Riley ed. Strength Training By the Experts. New York: Leisure Press, 1977, p. 61.

[14] Ibid, p. 70.

[15] Ellington Darden, "Frequently Asked Questions About Muscle, Fat, and Exercise," Athletic Journal, November, 1975, pp. 85-89.

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[17] Ibid, p. 88.

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